RP 902 Lean in an Operational Environment

The following recommended practice (RP) is subject to the disclaimer at the front of this manual. It is important that users read the disclaimer before considering adoption of any portion of this recommended practice.

This recommended practice was prepared by the AWEA Quality Committee. The committee would like to thank:

Primary Author: Scott Mathieu, EDP Renewables North America LLC
Contributing Authors:
Thomas Brazina, EDP Renewables North America LLC
Ryan Griffin, Mortenson Construction
Brandon Judish, NextEra Energy Resources
Gregory Lilly, E.ON Climate & Renewables North America
Fritz Oettinger, Vestas
Karen Tucker, Wanzek Construction, Inc.

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Purpose and Scope

The scope of “Lean In an Operational Environment” addresses applying lean concepts in wind site management operations.

Lean in an Operational Environment

1. Lean Overview

1.1. What is Lean?

Lean is a set of tools and practices aimed at reducing waste and improving reliability. Waste is defined as any activity that consumes resources but does not add value to a particular process. It also includes any product that the customers are unwilling to pay for. By eliminating waste and non-value added time and activities, one can shorten the timeline from when the customer orders the product or service to when the customer receives the full value of the product or service. As the provider of the product or service, one can reduce labor, materials, and cycle time with the ultimate goal of improving customer satisfaction and business performance in multiple areas, such as safety, quality, cost, and on-time delivery.

1.1. What is Lean?
(continued)

Perhaps the best way to understand the concept of lean thinking is to consider an example from everyday life. Everyone is familiar with the daily process of brushing their teeth. The steps of the process include applying water and toothpaste to a toothbrush, rubbing the brush vigorously over our teeth, spitting out the wastewater, rinsing the toothbrush, etc. The steps that directly contribute to the desired process output of clean teeth and fresh breath are those that provide value to the customer, in this case yourself. The resources expended when rubbing the brush over your teeth are surely value adds. But what about the time spent searching for the toothpaste tube in the drawer? This provides no direct value to the customer, but consumes time and energy. Perhaps you discover that you are out of toothpaste and must walk down to a basement closet where you store the inventory of unopened toothpaste tubes. This is also wasted time and motion in the brushing process.

Lean teaches us to first be aware of and identify the most common eight types of waste present in our processes. Lean also gives us tools to reduce or eliminate those wastes, thereby increasing the efficiency of our process. Lean is:

- A working attitude with a bias for action
- Focusing on adding value and eliminating waste
- Continuous improvement

1.2. History of Lean

For centuries, manufacturing was a craftsman's job. Most fabricated items such as furniture, musical instruments, and weaponry were handmade. This caused products to be very expensive, not replicable (each piece is unique), extremely variable in terms of quality, and highly dependent on the craftsmen that produced the product. As a result, affordability and mass production were unobtainable until the industrial revolution of the 1900s.

1.2. History of Lean
(continued)

During the early 1900s, the automotive industry was the most innovative of the era. Automobiles were manufactured all over the world; however, only Henry Ford had the innovation to develop mass production techniques. Ford Motor Company™ was the first company to implement the assembly line concept for building his classic Model T. He used various methods that divided labor and used hundreds of unskilled employees to perform one or two repeatable tasks, such as tightening two specific screws on the assembly line. Henry Ford was able to mass-produce his Model T Ford with high production rates at an affordable cost. This approach, though cost effective, was laden with issues of its own: quality and flexibility being the biggest challenge to overcome. The famous quote by Henry Ford is, “You can have any color, as long as it’s black”.

In 1936, Toyota Group™ was established. Toyota, fascinated with Ford's mass production assembly line, appointed an engineer to study the Henry Ford mass production operations. Japan at this time (1945) was heavily involved in World War II. Many of Japan's best and most intelligent men and women were at war.

Japan was weaker than ever and had limited resources at their disposal. Money for machinery, skilled labor, labor laws, and small market sizes were variables Toyota needed to overcome. Toyota knew they had to develop a company that was extremely flexible, utilize all of their limited machinery (no downtime), only manufacture exactly what the customer ordered, eliminate excess inventory, and empower every employee to own quality of all upstream workmanship. Toyota could not afford defects or quality of workmanship issues. Thus, the Toyota Production System (TPS) and lean were born.

In 1950, the TPS model was proven to be very successful. Using the Henry Ford mass production system as a benchmark, Toyota was able to assemble a car in 16 hours, an improvement over the 31 hours of Henry Ford. Toyota's biggest achievement was in quality and inventory. Toyota's employee empowerment approach reduced defects by 65% in comparison to Ford and minimized inventory from Ford's 2 weeks to only 2 hours. Over the next 38 years, Toyota's market shares rose from around 4% in 1950 to over 35% in 1988, surpassing Ford.

1.2. History of Lean
(continued)

From 1980-2000, universities and companies researched and developed many variations of the TPS to meet their own educational or business needs. This era is known as the “Lean Institute” phase and focused on implementing the TPS philosophies, tools, and methods in manufacturing industries. Companies quickly realized that these lean principles did not only apply to manufacturing, and from the year 2000 to today the “Lean Enterprise” era was established.

Today, industries such as banking, telecommunications, manufacturing, and energy implement lean tools and philosophies to foster continuous improvement and innovation, becoming industry leaders within their business sector.

1.3. Misconceptions about Lean Implementation

One of the most common misconceptions and misapplications of lean is thinking that lean means simply getting rid of process steps, process time, or process labor. Lean should never eliminate needed steps in a process. Remember that lean reduces waste and adds value. Setting arbitrary goals to reduce process cycle time or process costs by a certain rate, without understanding the value dynamics of your process, can lead to the elimination of truly value added steps. Instead, we need to first comprehensively define what is waste and what is value so that we can focus on reducing the waste in the process rather than the core of what we do well, i.e. the product and process value itself.

Lean may also be inappropriately described as a tool for manufacturing processes only. While it is true that lean has its roots in manufacturing, the principles of lean apply to all processes and all industries. Lean concepts and tools can be applied to all stages of wind generation, from construction to operations, from reducing crew travel and transportation of equipment during the construction of wind turbine to ensuring that time spent searching for tools during turbine maintenance is reduced by standardization and kitting of techniques. In addition, reducing motion also eliminates the opportunity for injuries. Implementation of a strong safety culture will also promote a positive lean culture.

1.4. Theory of Lean and Six Sigma

In any process that is consistently done over time, we can utilize Six Sigma to understand the amount of process variation a particular process is experiencing. The amount of process variation from a specific target is known as process variability. Identifying this variability identifies sigma values (how close are we to the target). Six Sigma is the most ideal process capability metric. Achieving a Six Sigma level process means the process achieves the desired target 99.99999% of the time. On the other hand, lean focuses on the individual steps within the process and ensures machine reliability and efficiency over time. Thus, the two complement one another and together are “Lean Six Sigma”.

In any process, we will find examples of the eight types of waste:

- **Transport:** movement of people, product, and information
- **Inventory:** storage of spare parts, work in progress, finished goods, or supplies
- **Motion:** reaching, lifting, bending, or other movements
- **Waiting:** for approvals, parts, equipment, or people
- **Over Production:** producing more than is needed or before it is needed
- **Over Processing:** doing more work than is necessary, producing tighter tolerances or grade than is necessary
- **Defects:** rework, scrap, all inspection activities
- **Talent:** under-utilizing people, the wrong person in the wrong job, lack of training or tools

An important concept in lean thinking is that of Kaizen. Kaizen is a practice of continuous improvement made by small, frequent changes for the better. Traditional process improvement thinking often focuses on large step-wise improvements and trying to achieve the “perfect” process before implementing a change. Kaizen looks for small changes that can be made every day, by everyone in the process, to ultimately drive a much larger cumulative improvement outcome.

Kaizen practices can be formalized within an organization or process with simple practices such as a daily improvement board or stand up improvement meeting. At the beginning of each shift, team members can gather for several minutes at the improvement board and each team member writes down one way they will improve their work during the coming day or one way in which they improved the process in their last workday.

2. Typical Lean Concepts

Before we venture into specific lean concepts, it must be communicated that these tools are used to solve specific business problems. For example, you would never use a hammer to unscrew a nut, and lean tools are no different. You would not use value stream mapping to determine the root cause of a particular failure in a gearbox. These tools are simple to use when you know where and when to apply them.

2.1. Value Stream Mapping: Identifying Process Gaps

Value stream mapping is a lean method used to analyze the current state of function in a value chain and design an optimized future state. A value chain is any process or series of physical events that delivers a product or service to a customer. Value stream mapping seeks to identify each task that discretely adds value to the overall process, displaying the measured time, labor, information, and material inputs and outputs of each task. The value stream map is based on the concept of one-piece-flow, or following a single 'component' through a series of value added steps. Knowing and documenting the current state of a process is the first step in working toward an ideal future state. Understanding the concept of 'flow' is also important to the value stream concept, as it seeks to optimize the efficiency of the overall process not the individual efficiencies of every resource involved. This allows the user to visualize where delays and waste may occur in the broader process, even when each sub-task may appear to be optimized.

To create a value stream map, representatives from each functional area in the process should participate. The engagement of the team is key both to ensuring the greatest accuracy and to facilitating conversations that may not occur in the day to day working environment. Not all participants will be able to envision an optimized future state. However, they may be able to identify smaller opportunities to improve flow. It's desirable for the team to walk and observe first hand the physical process taking place, including measurement of inventory, cycle time, changeover time (duration between locations or events), resources required (number of operators and equipment), utilization of resources, rework or quality metrics, and available working time. Once the current state is measured and an optimized future state is envisioned, the gap between current and future state should be analyzed and an action plan developed to close the gap. Value stream mapping has been known to identify up to 99% of the non-value adding activities embedded in the current state. If done right, this lean method will result in tangible improvement steps that can be prioritized based on return on investment.

2.2. “5 Whys”: Fault Analysis or Root Cause Analysis

"5 Why" analysis is a foundational root cause analysis method designed to be applied more quickly and at a higher frequency than other, more formal root cause analysis tools. The primary goal of the "5 Why" analysis is to get to root cause by repeating the question "Why?" five times. With each consecutive iteration, the troubleshooter is brought closer to root cause. In some cases, multiple root causes can be identified, and each one may have its own series of "Why?". Generally, the fifth "Why?" will point to a process breakdown versus a physical problem. For example, a motor failure due to lack of bearing lubrication may ultimately uncover a faulty preventive maintenance program. "5 Why" analysis is a very good introductory method to other, more sophisticated forms of problem-solving.

2.3. Fishbone Diagrams: Turbine Fault Analysis or Root Cause Analysis

Similar to "5 Why" analysis, fishbone diagrams seek to define and illustrate underlying causes of a defect or source of variation. Fishbone seeks to classify sources of variation into categories such as people, methods, machines, materials, measurements, and environment. This method can be useful when a team is stuck or needs to go beyond the simpler "5 Why" approach and becomes a very good way to visualize multiple variables or root causes to a problem.

2.4. Single Minute Exchange of Die (SMED): Main Component Exchanges and Construction

Single Minute Exchange of Die (SMED) is a system for dramatically reducing the time it takes to complete changeovers. Shigeo Shingo, a Japanese industrial engineer who had a record of accomplishment of helping companies reduce changeover time by a documented 94%, successful implemented a SMED program that had benefits of reducing costs, increasing safety and quality, improving responsiveness to customer demand, reducing inventory levels, and allowing for improved startups.

While it may not be possible to reduce all changeovers to one minute, this process takes the approach that any downtime or non-value added time is eliminated. Like most lean tools, SMED is in other industries outside of just manufacturing. NASCAR™ pit crews, for example, employ SMED to further study and reduce the times of their pit stops. Because SMED is a relatively resource intensive process, sound judgement is necessary in order to determine where it can be best applied.

2.4. Single Minute Exchange of Die (SMED): Main Component Exchanges and Construction
(continued)

It may be the case, for example, that there are other areas that should be addressed first before changeovers. If mechanical reliability is a greater loss point than changeovers, it may make more sense to focus on implementing a reliability centered maintenance program before reducing changeovers. In this scenario, changeovers may have additional variability due to mechanical issues that arise and need to be corrected in that downtime.

2.5. Overall Equipment Effectiveness (OEE): Hourly or Energy Based Availability

Overall equipment effectiveness (OEE) is a standard for measuring manufacturing productivity. The concept was developed in the 1960s to evaluate how effectively a manufacturing operation is utilized. Because results are expressed as a percentage of standard, OEE can be compared between different operations or industries. To achieve a score of 100% OEE, a system must run at 100% quality: zero defects, 100% performance, and as fast as system design speed allows. It must also run at 100% availability: no stop time. By measuring OEE and the underlying losses, productivity can be systematically improved. Variances from standard can be graphed in a Pareto diagram, and improvement plans can be made to address the highest impact losses from system performance. Because OEE takes into account all loses, it can be considered a holistic measure of performance.

2.6. 5S (Sort, Set, Shine, Standardize, Sustain): Inventory and Tool Management

5S is a process to reduce waste, improve safety, and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results. 5S addresses many of the eight wastes of production, and many organizations use 5S to set a foundation for developing a continuous improvement culture. 5S is equally applicable and effective in all sectors.

The process was developed in manufacturing and was popularized by Toyota. The term 5S references the first letter of the Japanese words for each step in the process. English translations are not exact but typically maintain the nomenclature. 5S requires the user of a workspace to be directly involved in the organization and sustainability of the process. Consistent utilization of this method can lead to a greatly increased sense of ownership for equipment, with gains in safety, quality, morale, and productivity.

3. Applying Lean Concepts in Wind Site Management Operations

3.1. Organizational Alignment and Commitment to Continuous Improvement

As companies implement continuous improvement to streamline processes and reduce costs, too often lean tools are deployed as the objectives rather than as specific project goals. Unfortunately, training for these tools is typically done in a shotgun approach, delivering an unintentional message that short-term results are the desired endgame. These project initiatives may result in respectable cost savings, but on their own will never release the full potential of people in an organization unless reviewed and aligned with corporate goals. So before anyone trains and assigns champions to implement 5S principles, standardize a service, or optimize warehouse inventory, a more fundamental focus on team culture and organizational alignment needs to be framed at all levels.

Since “you cannot improve what you can’t measure,” a lean program will typically start with an event defining the organizations key metrics, including how they will drive department, team, and finally individual day-to-day measures. Every company has a mission statement or a set of goals based on visions and values that coalesce into a written declaration of its core purpose of existence. The first stage in developing a continuous improvement culture is for everyone to understand the organizational measures and how they will affect the strategic goals.

Most organizational measures can be organized into one of Kaplan and Norton's four categories of a balanced scorecard: customer, financial, process, and learning and growth[1]. In addition, manufacturing and heavy industry typically use safety as a fifth category. With long-term and annual strategic goals for reference, each department and team should brainstorm key measures that align their daily activities with the corporate goals.

When developing these measures, no more than one or two per category are necessary. Using a benchmark, like the 31 seconds visual management rule, basic dashboard metrics would provide anyone a three second process overview, a 10 second display of trends, and in 20 seconds identify the solutions and proposed improvements currently being pursued. Then, by creating tiered metrics, an organization can use dashboards to drive daily team huddles (stand up or green area meetings), further aligning management and supporting departments with field operations in vision and direction. This not only helps provide clear instructions and goals for individual accountability, but also enables better information sharing and planning to address critical issues as they develop. These are all important first steps in developing and maintaining a continuous improvement culture.

3.2. Cultural Onsite Enablers

A company culture is generally defined as the collective way in which employees interact to make the day-to-day, large and small, decisions that execute the organization's vision and strategy. Even with all of their strengths, lean tools arguably only contribute 20% to a successful continuous improvement program. However, if an organization has a strong lean culture, it will contribute the other 80%. Hence, once the foundational strategy is clear to everyone and measurement goals are established, additional cultural enablers can be developed into a framework that promotes a philosophy of seeking perfection in all work processes.

Clear goals and metrics, along with daily communication, are clearly important in a lean culture as described. Still, much of a cultural foundation lies in linking common HR behavior expectations to lean implementation rules and standards. The processes of recruitment, formal orientation, training, individual development, and reward systems all play a large part in giving employees the basic skills and instincts to contribute to company improvements. And once these links have been shaped, the focus must be redirected to leadership, which needs to gain the respect of new employees through both coaching and mentoring performance objectives.

Organizational alignment and culture building are not complicated, but the processes are broad in scope. Development of a lean culture needs to cascade through an organization and be introduced from the moment a potential candidate is interviewed, through orientation and on-the-job training, and continue well into a person’s career with the company. This enables leadership to demonstrate humility by constantly engaging employees and providing them with personal learning and development opportunities for growth.

3.3. Common Mistakes and Lessons Learned

There is plenty of opportunity to learn from poorly implemented lean programs. The internet is littered with case studies and war stories of improvement projects gone wrong. For wind energy, the top ten common mistakes can be summed-up as follows:

3.3. Common Mistakes and Lessons Learned
(continued)

3.3.1. Starting a lean transformation without experienced and professional help

It is very difficult to complete a lean event if there is lack of training or involvement in continuous improvement work. Whether the team draws on an internal lean facilitator or contracts an external expert, it is always best to employ someone with Kaizen experience to work with teams during the start of any project or major program.

3.3.2. Relying completely on a lean champion

On the other hand, a strong and committed implementation team is necessary for any project to be successful. External experts typically do not have the authority or commitment to make things happen that are necessary to fully optimize a process.

3.3.3. Too many conflicting metrics

The KISS (Keep It Simple Stupid) principle needs to be closely followed in regards to dashboards. One measurement per category is ideal, but never have more than two. While there may be dozens of key performance indicators (KPI) being tracked by various teams or departments for each category, only the primary metrics should be displayed for daily huddle meetings.

3.3.4. Continuous improvement not linked to a business plan

This mistake is easily rectified through communication. Before any actions are initiated, each group or individual needs to submit a brief plan or project charter. The proposal must be quickly reviewed, compared to the annual plan and/or other projects in queue, and approved by a designated leader or cross functional team. This is to avoid one of the worst “wastes”: doing work that does not need to be done at all.

3.3.5. Not providing adequate training, facilitation, and follow-up

A few hours or days of training will not create an expert. Continuous improvement teams need to be developed using a combination of classroom training, project work, and benchmarking. And even when a skilled group is available, a facilitator needs to be identified or trained to direct and focus team progress.

3.3.6. Believing a tool, such as 5S implementation, can be completed in a day or even week

One can seldom complete the "Set in Order" step of a 5S project in a week. Two or three rounds of review are normally required to be sure excess material, tools and equipment are properly dispositioned. A process checklist with defined steps is the best way to ensure sustainability and accountability.

3.3.7. Treating symptoms and not determining root cause

Unfortunately, some problems get fixed only to reoccur. Lean tools such as the “5 Why” analysis are specifically designed to guide a team to define the root cause. While these methods take more time and discipline, solving a reoccurring problem normally saves a lot of time and cost.

3.3.8. Believing you will achieve a lean transformation only by applying lean tools

While all of the lean tools can help solve problems and reduce costs, creating a lean culture is the endgame.

3.3.9. Lack of top management understanding and commitment

No program will ever survive leadership apathy. Lean needs to be understood and promoted by top management. Employees are inspired to improve by leadership “walking the talk” and expecting to see management embracing change and pursuing perfection.

3.3.10. Making the statement and believing “we have completed a lean program”

It is called “continuous improvement” because the journey is never complete. When you stop improving, there is always another entity willing to further innovate and claim your business market share.

4. Lean and Site Management Principles

Many people ask about the difference between quality ISO standards and lean implementation. The best way to communicate the difference is to recognize that there is not a difference. Quality by itself is an overarching umbrella that uses various methods to improve standards and improve operations. Lean is the agent that bonds us to our ISO requirements and maximizes the value of our product to our customers. Top organizations may be ISO compliant, with rigorous quality manuals and procedures, but lack innovation, culture, and continuous improvement.

Lean innovation takes a good quality program to the next level of operational excellence. In order to achieve this level of operational excellence, a company must have the basic quality programs in place. The quality program will provide an essential foundation and further establish a corporate culture of structure and continuous improvement. Companies that view the certification as the end objective (check the box) will not be as successful as companies that implement a lean program to accompany their quality program. A lean program will further enhance a company's quality program and improve the day-to-day operations. Reducing safety incidents, improving product reliability, and improving customer satisfaction takes continuous improvement. The lean tools will only help facilitate these improvements.

4.1. Metric Development and KPI Management

4.1.1. Key performance indicators (KPI) are set by management.

- Goals and objectives are identified through management and customer expectations.
- Quality expectations, or customer requirements, are translated by management.

4.1.2. Metrics are reflective of control point data.

Metrics are the data points that reflect process or product performance. These metric points are identified by the quality plan to support the KPIs.

4.2. Accountability and Ownership

4.2.1 Quality Plans: Proactive versus Reactive

Quality planning should be performed in conjunction with other planning processes. To plan for quality, the team identifies the quality requirements and standards for the deliverables and documents how the project will demonstrate compliance.

The items to review to assist in the identification of quality requirements include, but are not limited to, the following:

- Project charter or scope statement describing the deliverables and acceptance criteria
- Work breakdown structure (WBS) identifying each deliverable
- Cost or budget outlining constraints to providing the deliverables
- Schedule highlighting the timeframe to deliver the project
- Risk register identifying information and threats to successful project completion
- Outside factors, including regulations or operating conditions, impacting the project
- Organizational process assets, including quality policies, supplier management programs, and lessons learned, assisting the project

As part of identifying the quality requirements, the team is to be aware of the benefits of meeting quality requirements, including less rework, higher productivity, lower costs, and increased stakeholder satisfaction. The tradeoff to delivering a quality project is the “cost of quality”, including the costs incurred in preventing nonconformance to requirements, inspecting the deliverables for conformance, and reworking a deliverable to meet requirements.

4.2.2. Quality Assurance (QA) and Quality Control (QC)

QA can be defined as a set of activities designed to ensure that processes are established ensuring the project deliverables comply with relevant quality standards throughout the project lifecycle, including project audits and process checklists. QA is also the process of auditing or assessing the quality requirements and processes during the production of the deliverables to ensure the appropriate quality standards and operational definitions are used.

4.2.2. Quality Assurance (QA) and Quality Control (QC) (continued)

Typically, QA activities are performed during project planning and execution. QA is closely related to QC in that QA processes utilize measurements obtained during QC to adjust or improve processes, ensuring non-conformances are prevented. QA activities may be conducted during the specific project being worked or may be part of an overall company or business unit initiative for continuous improvement.

QA activities can involve, but are not limited to, the following:

- Reviewing performance measures (How is the project performing compared to plan?). Ongoing issues may indicate non-conformance.
- Examining project deliverable status (Are the deliverables acceptable?). Rushed deliverables increase non-conformance.
- Determining schedule progress (What is the schedule status versus plan?). Nonconforming deliverables may be causing rework.
- Evaluating project costs incurred (What is the current actual project cost versus plan?). Nonconforming deliverables incur cost to correct.

Typically, QA activities are performed as part of a self-assessment or audit process and should complement a lessons learned process that includes identifying best practices, opportunity areas, performance gaps, sharing information, and proactively offering assistance in a positive manner to improve.

The results of QA activities can include change requests to either rework specific deliverables or to modify deliverables to meet the quality requirements. Additionally, corrective and preventative actions can be identified to address current issues and to prevent reoccurrence.

QC can be defined as a set of activities designed to evaluate the deliverable to ensure compliance with relevant quality standards throughout the project lifecycle, including inspection and testing. QC is product or service oriented.

4.2.2. Quality Assurance (QA) and Quality Control (QC) (continued)

Performing QC is the process of inspecting and measuring the deliverable against the quality requirements. QC activities are performed throughout the project and involve the measurement of 'planned' versus 'actual' results.

The planned results, or acceptance criteria, are defined during the planning phase of a project. As the deliverables are produced, they are measured with actual results. As long as the actual results are within the tolerance range, or acceptable variance, then the deliverable is in conformance. If the actual results are outside the tolerance limits planned, then the deliverable is in non-conformance and follows a disposition process. The disposition process determines if the deliverable requires reworking, scrapping, or accepting through a change request process.

QC activities can involve, but are not limited to, the following:

- Inspection of project design, both internally and externally created
- Details drawing completeness and accuracy
- Designing input/output (I/O) points
- Bill of material (BOM) completeness and accuracy
- Vendor surveillance or inspection program
- Establishing inspection hold points for critical material
- Ensuring vendor is producing material within design limits
- Inspection of received materials against the design or order upon receipt
- Identifying that the correct part numbers, quantities, and items are delivered
- Implementing a disposition process for non-conforming materials

4.2.2.1. Inspection and Test Plans (ITP) for Identified Activities

ITPs are activity roadmaps with the procedures, skills, and tools needed to perform the sequential tasks, with control points for the inspections and data identification.

4.2.2.2. Skill Sets and Qualifications

Identify in the quality plan the necessary skill sets and qualifications to perform the identified tasks.

4.2.2.1. Resources

Identify in the quality plan the necessary resources to execute the plan. Resources may include workforce, equipment, documentation, software, hardware, and logistical needs.

4.3. Sustaining Results and Continuous Improvement

4.3.1. Monitor, Control, and Improve

Monitor and control involves review of the QA and QC activities to ensure the deliverables are produced meeting the quality requirements. Controlling project quality helps ensure non-conformances are identified prior to project close. The benefits of meeting the project quality requirements are to be reviewed against the cost of quality from following the value added processes to meet or attempt to meet the quality requirements.

Tools and techniques utilized to monitor the project quality include, but are not limited to:

- Identification of deliverable non-conformance
- Control points
- Variance analysis
- ITPs with control points
- Project self-assessments
- Project audits
- Change management processes and associated change logs
- Performance reports
- Internal audits or daily walk downs

Review deliverable quality requirements on a defined periodic basis to ensure they are being met or the correct preventative actions are established. Additionally, use data reviews to use leading indicators, as well as lagging indicators, to determine action.

4.3.2. Supplier or Contractor Quality Plan Assessments (Oversight and Assurances)

All quality plan requirements are cascaded throughout the supply base and are ensured through documentation and verification.

4.3.3. Documentation and Record Management (Data Package Requirements)

All associated documentation and records are formalized and maintained throughout the project. All assurances are made to verify correct procedure usage, record integrity, and maintenance.

4.3.4. CAPA System (Corrective Action/Preventive Action)

An effective CAPA system is in place to both prevent issues from occurring and to identify issues and concerns that have occurred to ensure corrective action and to prevent recurrence.

4.3.5. Communicate

The process of communicating and consulting with key stakeholders on quality management status is facilitated through the use of project self-assessment, audit reports, inspection reports, and cost or schedule updates. This communication may also be part of a non-conformance or corrective action program. The team is to document and communicate the non-conformance, along with the associated corrective action, preventative action, and possible lessons learned. At a minimum, deviations from quality standards are required to be recorded on the project report monthly.

5. Warehouse and Tool Management

5.1. Warehouse Optimization

In the 1980s, the Toyota Production System was introduced in North American manufacturing as “Just-In-Time” (JIT) inventory control. Basically, the concept was that inventory is an insurance policy. As equipment, processes, and operator skill levels improved throughout an operation, the raw materials, component parts, works-in-process, and finished goods inventory throughout the manufacturing process dramatically decreased. In the automotive industry, this meant millions of dollars of capital were freed up with a successful JIT program. Optimizing space utilization, material flow, order picking, and dock operations create significant cost savings in material and labor.

At the site level in the wind industry, most warehouse facilities are very small in comparison to the manufacturing industry. An efficient use of space is always desired in construction and service operations to control cost. Whether the building is new or an existing property, the first step in improving material and work flow is to use the value stream mapping tool. Wind farm warehouse layouts are fairly standard in design, consisting of pallet racking, small parts shelving, oil storage, oil containment, and shipping/receiving areas. With limited floor space, the goal is often simply to use all horizontal and vertical space as effectively as possible, reducing time to pick and stage parts that could otherwise be spent more productively. For example, oil management can be optimized by setting up a rack with the different oils, coolants, and cleaners in bulk storage tanks. The tanks can be easily filled by pumps and dispensed by hoses connected to a valve header.

5.2. Metrics and Accountability

The standard measures for monitoring the health of a warehouse are inventory accuracy and total cost. Measurement of inventory turns can also be applied. However, many stock decisions are based on component lead-times, and inventory turns often are dictated by the make, model, and age of the equipment. Inventory levels can balloon or become inaccurate very quickly if not kept in check. Non-inventory items, especially, tend to grow exponentially if not tracked by piece or part count. Most non-inventory items are written off and have no assigned cost, which makes information difficult to share with other sites. A good practice is to establish a “blacklist” of non-inventory parts that can be shared, especially after initial construction, otherwise the items end up lost or damaged in the yard or warehouse without a chance of recovering value, except, inevitably, as scrap.

5.2. Metrics and Accountability
(continued)

Every warehouse needs a trained associate to maintain the stock and to maintain the integrity of the material requirements planning (MRP) system that tracks inventory levels and re-order points. While great effort is typically paid to training technicians, formal inventory control training is usually non-existent, consisting of basic MRP software data entry with no warehouse or logistic training. With wind farm sizes varying dramatically, it is often not viable to have a dedicated inventory coordinator onsite. In either case, an employee with the aptitude and organizational skill needs to be identified and made accountable. Bar coding can be used to enter and relieve stock, for example. And with many scanning systems, the parts can be scanned and assigned directly to a work order. Ultimately, there needs to be one local associate assigned to guarantee the integrity of the part levels through daily or weekly cycle counting. A great resource to help setup inventory and logistic training is the American Production and Inventory Control Society, or APICS™. Their website offers learning resources and an industry certification to use as a benchmark.

6. Technician Continuous Improvement

In order to create a quality culture, it is important to ensure that technicians receive skills and knowledge regarding the use of data driven problem-solving. This could be analysis for special cause variation or the use of Six Sigma tools for common cause variation. In an ideal state, promotions to more advanced wind technician levels include the requirement to have the data driven problem-solving skill set in place. This includes both the academic and real world application of quality tools.

A format used for special cause variation analysis is the “Quality Improvement Story”. This is a seven step problem-solving process in which the team uses data to identify a project indicator and sets a target for improvement. A tie to the customer focus and company strategy is established, ensuring focus remains on the primary key objectives as defined by the customer. Project teams gather additional information, using tools like Pareto graphs, to further scope the problem. Then, they use an additional tool for analysis, such as the fishbone diagram, to brainstorm potential causes. The potential causes are verified through testing. The testing performed must identify the true root cause of the problem and any contributing factors.

6. Technician Continuous Improvement
(continued)

Countermeasures used to reduce or eliminate the root cause are identified through the use of a countermeasure matrix, which helps the user identify potential corrective actions, costs, and risks of implementation. Results are proven through plotting the post-countermeasure project indicator data and comparing against the initial target. The team then works to ensure that countermeasures are replicated across the site and across the applicable turbine technology in the standardization step. Remaining actions and the next project are identified in the future plans step.

Common cause variation is addressed through Six Sigma's "Define Measure Analyze Improve and Control" (DMAIC) methodology and is recommended for the wind operations management ranks. The technicians may be called in to participate in a measurement systems analysis or process mapping exercise.

6.1. Continuous Improvement Process for Technicians (Quality Belt Training)

All technicians are required to take quality training to reinforce the following concepts:

- Project charter
- "Supplier - Input - Process - Output - Customers" (SIPOC)
- Voice of customer
- Process map
- Data collection plan
- Indicators and metrics
- Graphs (line graphs, bar charts, and Pareto graphs)
- Brainstorming
- Affinity diagrams
- Cause and effect (fishbone diagrams)
- "5-Why" analysis
- "Non-Value Add / Value Add / Business Value Add" (NVA / VA / BVA) analysis
- Root cause verification
- Future state process map
- 5S (Sort, Set, Shine, Standardize, and Sustain) or 6S (Safety)
- Countermeasures matrix
- Pilot countermeasures
- Process control plans
- Visual process management
- Kanban (a visual signal used to trigger an action)
- "Poka Yoke" (mistake proofing)
- Standard work

6.2. Organizational Cultural Reinforcement

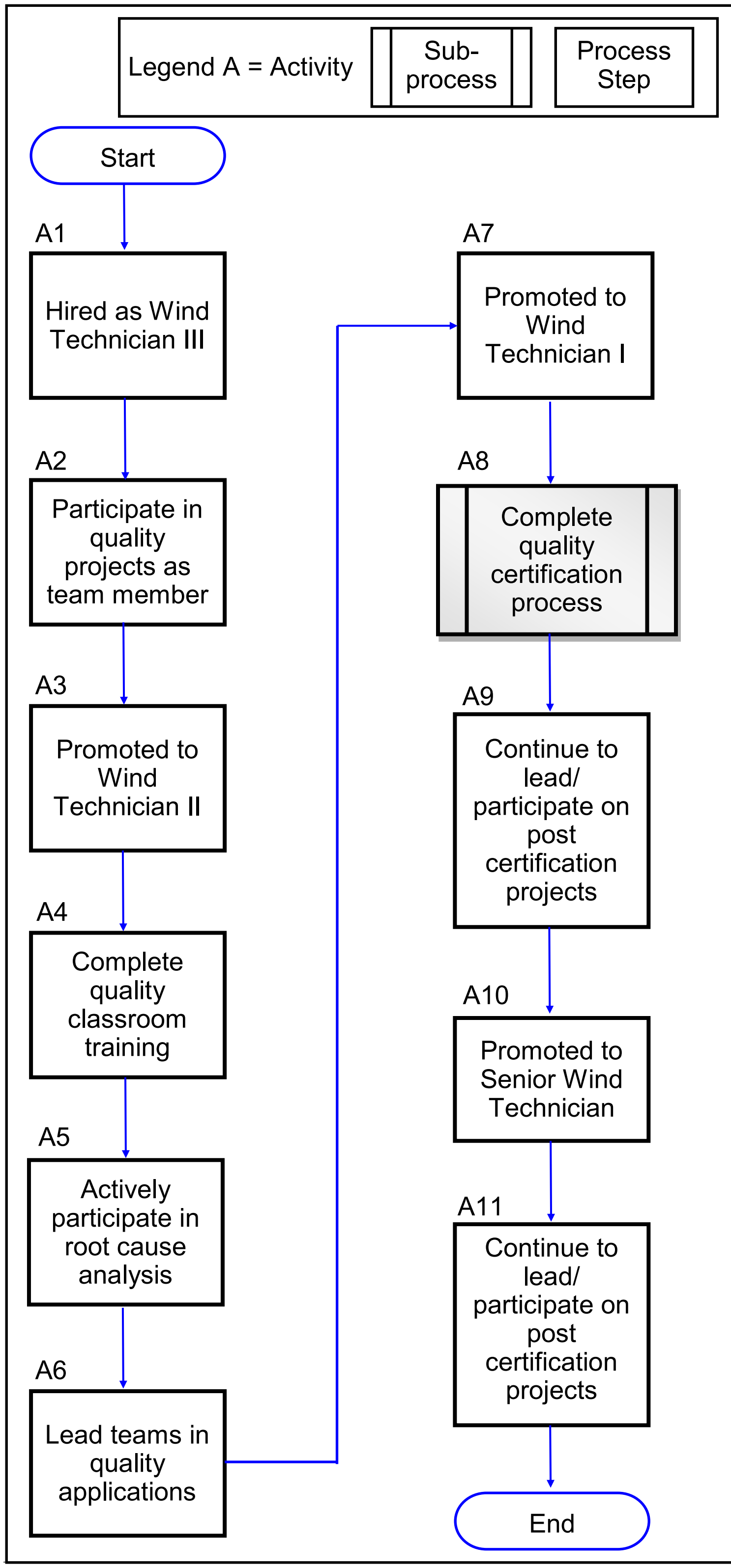
The company should provide opportunities for the technicians to compete at both the regional and corporate level with their completed quality projects. The quality projects must demonstrate measurable savings to the company and enable replication of countermeasures across the wind turbine technology. The competitions will help to share learnings from other projects and allow the technicians to develop relationships with other team members across the organization. The competitions should be held at an annual frequency and help to improve employee engagement in the area of quality.

6.3. Technician Ownership and Accountability

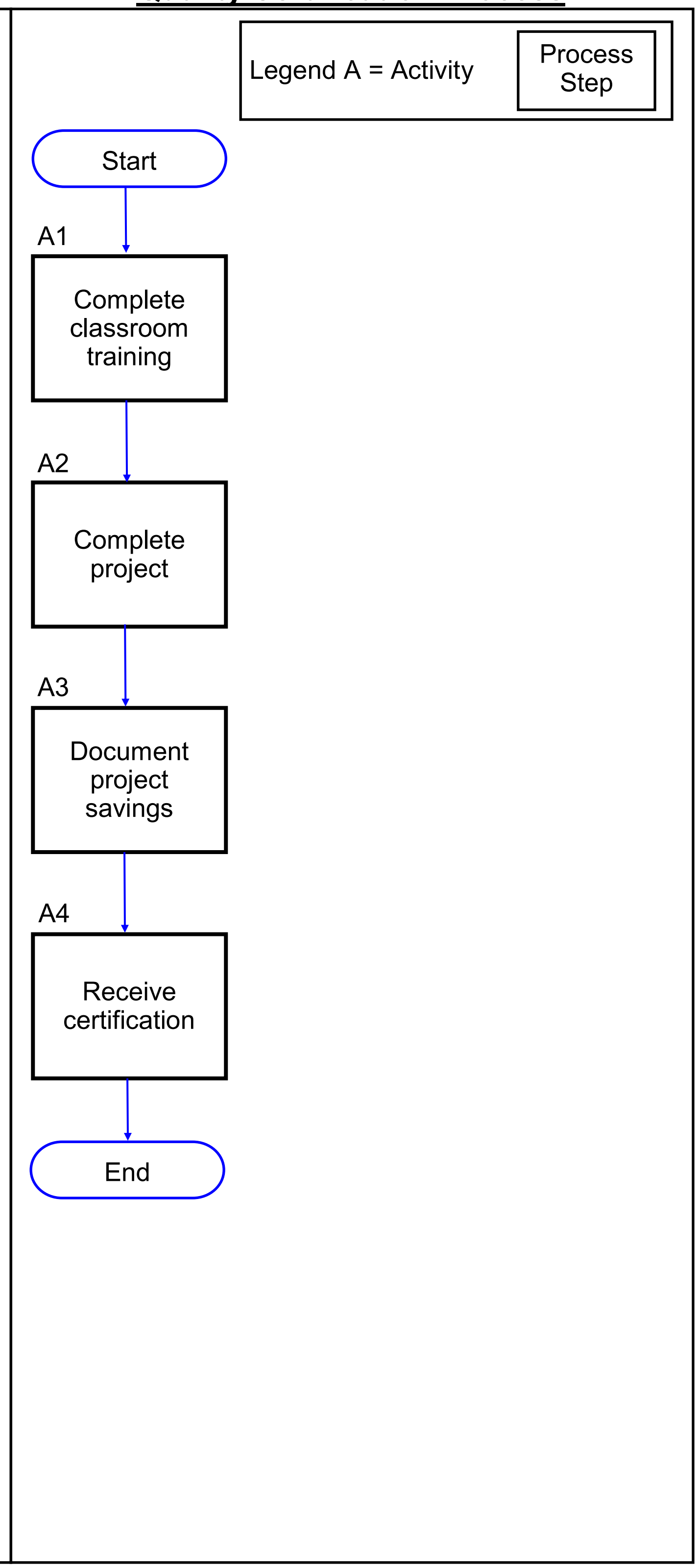
Technician accountability is established through the following two processes (note that participation in quality projects is expected for each rank):

6.3. Technician Ownership and Accountability (continued)

<u>Quality Requirements for Promotion Process</u>



<u>Quality Certification Process</u>



6.4. Lean Workshops and Frequent Kaizen Events

The company will provide opportunities for technicians to provide feedback on lean workshops and schedule Kaizen events. These types of activities are scheduled based upon the needs and priorities of the organization.

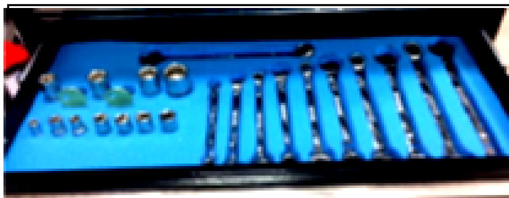
A technician would not be expected to lead the event; however, they must be part of a team for the duration, which lasts three to five days, in order to provide their field experience and technical knowledge of the problem. The event normally requires process mapping. The technician works with the team to identify areas of the process in which there is opportunity for improvement. The technician would help to identify value add, business value add, and non-value add activities. A technician may even be called in for a short duration in order to provide feedback on the activities of the team or to offer their knowledge for the problem at hand. An example would be to help identify which types of waste exist in the process, including transportation, inventory, motion, talent, waiting, over-production, over-processing, or defects.

Participation in these events can present the technician with opportunities to work on an individual “Quality Improvement Story”. Data can be collected, after the process is mapped and indicators are identified, for measuring the process health. Any gaps in performance would be good candidates for potential “Quality Improvement Story” projects.

Countermeasure identification and implementation in lean workshops and Kaizen events are based upon team consensus and management discretion utilizing the data driven problem-solving methodology.

7. Practical Examples

7.1. Warehouse Management



Shadowing tools allows for quick visual inventory

Initials are stamped into a set of chits, for individual and daily use, to rapidly locate a tool if needed. Management chits leverage a distinctive color for calibrations or repair situations

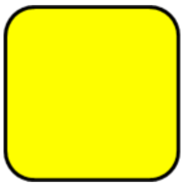
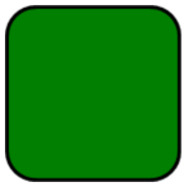
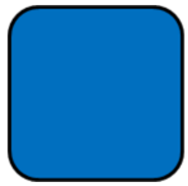
Example 1: Tool Shadowing and Chit System

A custom system was built that reduces the weight and space of tanks up tower, while decreasing the time deliver nitrogen.

This system came from a collaborative, multilevel improvement effort including technicians, site mangers, and operations support team members

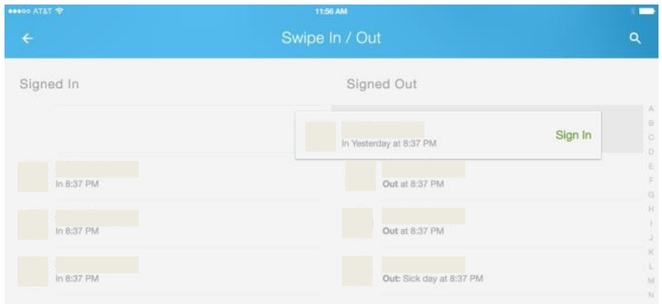
Example 2: Custom Tool Kits and Custom Nitrogen Pump System

7.1. Warehouse Management
(continued)

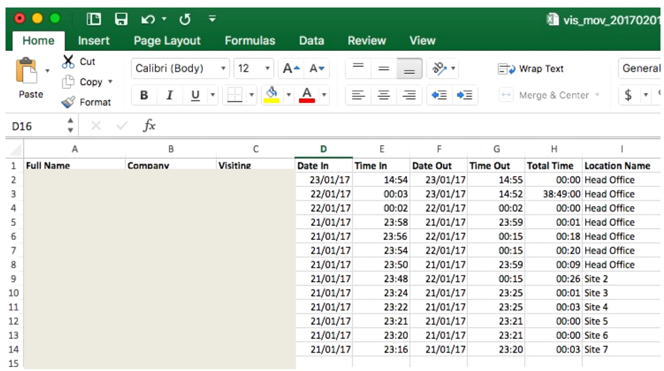
				
Traffic Lanes	**Safety Needs**	**Work Area**	**Restricted Access**	**Clear per Code**
Designated egress ways for foot travel	Clearance for eye wash, first aid, and spec packs	General label for work areas and tool storage	Examples include: forklift, defective parts, oil storage	Clearance for electrical panels and fire extinguishers

Example 3: Visual Controls and Floor Tape

7.1. Warehouse Management
(continued)



Front end user experience allows employees to drag their name "in" and "out" while visitors can create profiles.



Full Name	Company	Visiting	Date In	Time In	Date Out	Time Out	Total Time	Location Name
			23/01/17	14:54	23/01/17	14:55	00:00	Head Office
			22/01/17	00:03	23/01/17	14:52	38:49:00	Head Office
			22/01/17	00:02	22/01/17	00:02	00:00	Head Office
			21/01/17	23:58	21/01/17	23:59	00:01	Head Office
			21/01/17	23:56	22/01/17	00:15	00:18	Head Office
			21/01/17	23:54	22/01/17	00:15	00:20	Head Office
			21/01/17	23:50	21/01/17	23:59	00:09	Head Office
			21/01/17	23:48	22/01/17	00:15	00:26	Site 2
			21/01/17	23:24	21/01/17	23:25	00:01	Site 3
			21/01/17	23:22	21/01/17	23:25	00:03	Site 4
			21/01/17	23:21	21/01/17	23:21	00:00	Site 5
			21/01/17	23:20	21/01/17	23:21	00:00	Site 6
			21/01/17	23:16	21/01/17	23:20	00:03	Site 7

Back end system data provides a simple export of attendance records eliminating the need for duplicate entry, mistake prone paper time cards.

Example 4: Cloud Based Sign-in Board

References

[1] balancedscorecard.org. Balance Scorecard Institute, "Balanced Scorecard Basics," 2017. [Online]. Available: https://www.balancedscorecard.org/BSC-Basics/About-the-Balanced-Scorecard.

American Wind Energy Association
1501 M St. NW, Suite 900
Washington, DC 20005
www.awea.org